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Composition of the Incidental Kill of Cetaceans in Two California Gillnet Fisheries: 1990-1995

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ABSTRACT

In July 1990, an observer program was established to collect data on the bycatch of the drift and set gillnet fisheries operating off the coast of California. These data are used for estimating mortality and for further studies of the biology of the species impacted. To date, 16 species of Cetacea have been identified in the observed incidental kill of the gillnet fisheries. In the drift gillnet fishery, observers reported 348 cetaceans incidentally killed, and biological samples were collected from 83.6% of these animals. The common dolphin, *Delphinus delphis*, was the most frequently observed species entangled in the drift gillnet fishing gear and comprised 48.6% of the observed incidental kill. In the set gillnet fishery, 20 cetaceans were observed killed, and biological samples were collected from five of these animals. The harbour porpoise, *Phocoena phocoena*, was the most frequently observed species entangled in set gillnet gear and comprised 80% of the observed incidental kill. In this report, we summarise, by species, the age, the total body length and the sex composition of cetaceans sampled from the incidental kill in the drift gillnet fishery between July 1990 and December 1995, and in the set gillnet fishery between July 1990 and December 1994. We also demonstrate the value of collecting small samples of skin tissue for confirming species identification using molecular genetic techniques.

KEYWORDS: INCIDENTAL CATCH; COMMON DOLPHIN; HARBOUR PORPOISE; GILLNETS; NORTHEASTERN PACIFIC

INTRODUCTION

Data to document the incidental take of drift and set gillnet vessels operating off the coast of California were first collected by the National Marine Fisheries Service (NMFS) in 1990. The NMFS established an observer program for these fisheries under the exemption program outlined in the 1988 amendment to the Marine Mammal Protection Act. The Act's amendment specified a 5-year period during which fisheries continued to operate while data were collected to assess the status of marine mammal populations affected by fisheries (United States Federal Register, 1989). When the exemption program ended, the observer program for the California coastal gillnet fisheries continued as an integral part of the US management plan for marine mammal populations under the 1994 re-authorisation of the Marine Mammal Protection Act (Barlow *et al.*, 1995b).

The biological data collected from marine mammals incidentally killed in nearshore gillnet fisheries are used to determine the selectivity of fishing gear and to investigate the life history and structure of affected populations. Combined with the species-specific mortality estimates (Julian, 1996), these data are fundamental to the management of marine mammal populations affected by the gillnet fisheries (Barlow *et al.*, 1995a; b). The drift gillnet fishery operating off the coast of California targets swordfish (*Xiphias gladius*), the common thresher shark (*Alopias vulpinus*) and the short-finned mako shark (*Isurus oxyrinchus*), while the set gillnet fishery targets halibut (*Paralichthys californicus*) and the Pacific angel shark (*Squatina californica*) (Hanan *et al.*, 1993). The observed incidental kill of cetaceans and pinnipeds in these fisheries has been documented in a series of reports (Diamond and Hanan, 1986; Hanan *et al.*, 1986; 1987; 1988; 1993; Herrick and Hanan, 1988; Hanan and Diamond, 1989; Barlow *et al.*, 1994). Since 1990, species-specific mortality estimates based on data collected by NMFS observers have been prepared annually and are presented in Perkins *et al.* (1992a; b; 1994), Lennert *et al.* (1994), and Julian (1994; 1995; 1996). In addition to these reports, Julian and Beeson (In press) present a compilation of the annual mortality estimates. Summaries of the biological data collected from cetaceans by fishery observers through 1994 are presented in Lennert *et al.* (1994), Peltier *et al.* (1993; 1994a; b), and Robertson *et al.* (1995).

In this report, we summarise the biological data (i.e. species, sex, total body length and age) collected for cetaceans incidentally killed in the drift and set gillnet fisheries between 1 July 1990 and 31 December 1995. We also present data comparing species identifications made by fishery observers in the field to those made for the same specimens in the laboratory using morphology and genetic sequencing.

METHODS

Observers placed onboard California gillnet vessels record details of fishing activity and the incidental kill for each set (i.e. the unit of fishery activity). As much detail as possible is recorded on the incidental kill of cetaceans, including the geographic location, species, total body length and sex of each animal. Additional biological samples (e.g. gonads, teeth, skin and blubber, etc.) are collected from each animal when possible. Procedures for the collection of biological data are described in Perrin *et al.* (1976) and Jefferson *et al.* (1994). The data form used by fishery observers in this program is 'Appendix 4' in Jefferson *et al.* (1994).

Biological sampling

In the laboratory, the data and sample material collected by observers for each specimen were reviewed. This included an evaluation of the species identification made by the observer based on the diagnostic characteristics recorded, the examination of gonads to determine state of sexual maturity (Akin *et al.*, 1993), and the preparation of teeth to estimate age (Myrick *et al.*, 1983; Lockyer and Calzada,

1992). Age estimates for specimens collected were made by two readers (KMR and MDH) who read the prepared tooth sections independently three times each. When age estimates differed between readers, the readers re-examined the prepared tooth sections and a consensus age estimate was made, if possible. No consensus estimate of age could be made for five of the specimens in our sample, and for each of these animals we used an average of all age estimates as the best estimate of age. The maximum difference in age estimates made by the two readers was three years. Additional processing for a specimen may include examination of the stomach contents to identify prey (e.g. Perrin *et al.*, 1973; Bernard and Hohn, 1989; Robertson and Chivers, 1997), genetic sequencing of the skin sample to determine species identification (e.g. Baker and Palumbi, 1994; Dizon *et al.*, 1996; Henshaw *et al.*, 1997) or to incorporate the data in a study of population structure (e.g. Dizon *et al.*, 1992), and analysis of the blubber sample to determine concentration of contaminants (e.g. Calambokidis and Barlow, 1991).

Our summary of the biological composition of the incidental kill is presented in a table (Table 2) by sex and state of sexual maturity for each species. The median and range of the available estimates of age and total body length for all animals sampled by the NMFS fishery observers are shown.

Species identification

Species identification of specimens was determined or confirmed based on morphology (i.e. colour pattern and measurements) when a whole carcass or head was collected (see Heyning and Perrin, 1994). However, if only a skin sample was collected for a specimen, species identification was made by sequencing the mitochondrial DNA control region or cytochrome b gene using established protocols for purification and amplification of DNA (Saiki *et al.*, 1988; Palumbi *et al.*, 1991). A positive identification is made to the species with the fewest homologous base pair differences in pairwise comparisons between the sequence in question and available reference sequences (Baker and Palumbi, 1994; Rosel *et al.*, 1994; Dizon *et al.*, 1996; Henshaw *et al.*, 1997). A reference collection of control region sequences for nearly all cetacean species resident in the North Pacific is available at the Southwest Fisheries Science Center (SWFSC), including all species identified among the incidental take of the gillnet fisheries to date. Although we checked the identifications for a number of specimens collected, there are three groups of species incidentally killed in the California gillnet fisheries that are particularly difficult to distinguish in the field. These are the species of common dolphin: *Delphinus capensis* and *D. delphis* (Heyning and Perrin, 1994), the beaked whale species, family Ziphiidae (Henshaw *et al.*, 1997) and *Kogia* spp. (SWFSC unpublished data). When specimens belonging to one of these species groups were collected, a genetic sequence was used to determine species identification.

RESULTS

Biological sampling

In the drift gillnet fishery, 348 cetaceans were observed killed between 1 July 1990 and 31 December 1995 off the coast of California; biological data were collected from 291 (83.6%) of these. In the set gillnet fishery, the observed incidental kill consisted of 20 cetaceans, and biological data were collected from five (25%) of these animals taken between 1 July 1990 and 31 December 1994. There was no set gillnet fishery observer program in 1995, because fishery effort and ability to provide observer coverage was limited (Julian, 1996). Geographic positions for each specimen collected are shown in Fig. 1.

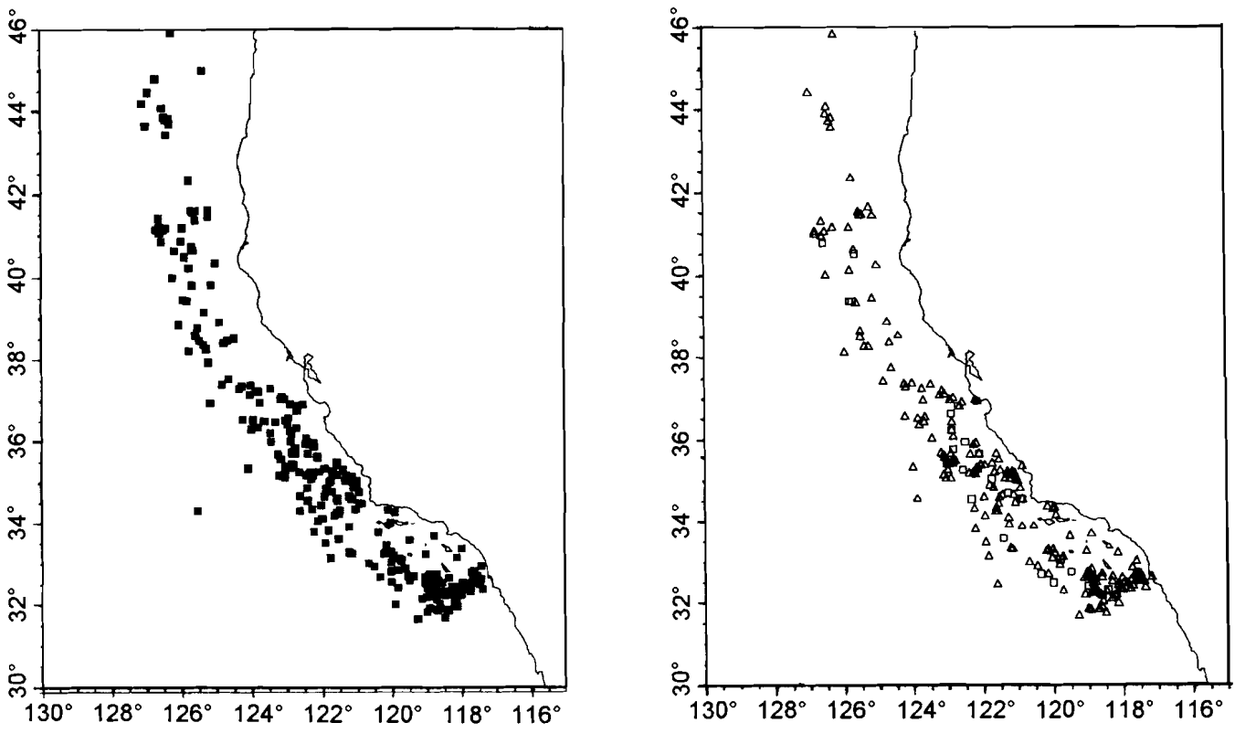

Fig. 1. Geographic location of (a) observed incidental kill and (b) collection of biological data from individual animals for the driftnet (triangles) and set-net (squares) fisheries operating off the coast of California.

Species identification

For 185 *Delphinus* specimens collected in the field, 166 *D. delphis* and 7 *D. capensis* specimens were identified using a combination of morphological and molecular genetic data. Observers committed to a species identification of *D. delphis* for only 39 of the 185 *Delphinus* specimens collected. In part, the appearance of so few specific species identifications is a reflection of the management scheme, which did not explicitly recognise the two species prior to Heyning and Perrin (1994). Of the 39 *D. delphis* field identifications, 30 identifications were confirmed by examination of morphological characters or the molecular sequence, four were determined to be *D. capensis*, and five could not be evaluated because no sample material was collected.

For the beaked whale specimens, the observer field identifications indicated 6 *Ziphius cavirostris*, 1 *Berardius bairdii* and 5 specimens unidentified to species. Examination of the control region sequences confirmed the *Z. cavirostris* identifications. However, the *B. bairdii* specimen identified in the field by an observer was determined to be a *Mesoplodon carlhubbsi* specimen based on the control region sequence. The specimens unidentified to species in the field included 4 *M. carlhubbsi* and 1 *M. stejnegeri* (Henshaw *et al.*, 1997).

Additionally, control region sequences confirmed the identification of eight *Globicephala macrorhynchus* specimens collected by observers but detected errors in two of the identifications. In these two cases, observers mistakenly identified *Grampus griseus* specimens as *G. macrorhynchus*. Finally, the field identification of a *Kogia breviceps* specimen was confirmed by its control region sequence.

Fishery selectivity

From 1990 to 1995, 16 species of Cetacea have been observed killed in the gillnet fisheries (Table 1). The two *Delphinus* species, *D. delphis* and *D. capensis*, accounted for 56.9% ($n = 198$) of the total observed incidental kill in the drift gillnet fishery. *D. delphis* occurred most frequently and comprised 48.6% ($n = 169$) of the observed kill between 1990 and 1995. *D. capensis* accounted for 2.0% and '*Delphinus* sp. unidentified to species' accounted for an additional 6.3% of the total observed kill of cetaceans. Several other species are observed killed nearly every year, albeit in small numbers (i.e. 5-9% of the total observed take): *Lagenorhynchus obliquidens, Phocoenoides dalli, Lissodelphis borealis, G. griseus,* and *Z. cavirostris*. *Phocoena phocoena* is the most frequently taken species in the set gillnet fishery (90%, $n = 18$) and was observed taken each year in which the setnet observer program operated (i.e. 1990-1994). The only other species observed incidentally killed in the set gillnet fishery was a *Delphinus* specimen that was unidentified to species (Table 1).

Table 1

Summary of 1990 - 95 observed incidental kill (column label: 'Kill') and the number of animals with biological data collected (column label: 'Sampled') by species from the (a) drift gillnet and (b) set gillnet fisheries that operate off the coast of California. The percent coverage data are provided for reference and are an estimate of the percent of all trips made by each fishery that were observed (Julian and Beeson, 1997).The sampling of all *D. capensis* specimens observed killed is an artefact caused by the fact that species identifications were made in the laboratory based on examination of the morphological or molecular genetic data available for these animals.

(a) Driftnet

	1990		1991		1992		1993		1994		1995		Total	
Percent Coverage	4.4		9.8		13.0		13.5		18.0		16.3			
Species	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled
Delphinus delphis	4	4	38	37	39	39	24	23	26	26	38	37	169	166
Delphinus capensis	0	0	0	0	2	2	0	0	1	1	4	4	7	7
Delphinus spp.	4	2	6	2	8	4	4	3	0	0	0	0	22	11
Lissodelphis borealis	0	0	7	6	2	1	7	7	7	7	9	8	32	29
L. obliquidens	3	2	5	5	3	3	2	2	3	3	1	1	17	16
Grampus griseus	0	0	5	2	5	4	4	7	1	1	6	5	21	19
Tursiops truncatus	0	0	0	0	3	2	0	0	0	0	0	0	3	2
Stenella coeruleoalba	0	0	0	0	0	0	0	0	1	1	0	0	1	1
G. macrorhynchus	1	0	0	0	1	1	11	6	0	0	0	0	13	7
Orcinus orca	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Phocoenoides dalli	1	0	2	1	1	1	9	9	2	2	1	1	16	14
Unidentified Ziphiidae	1	0	0	0	3	0	0	0	1	0	0	0	5	0
Ziphius cavirostris	0	0	0	0	6	2	3	1	6	4	6	3	21	10
Mesoplodon carlhubbsi	0	0	0	0	3	3	0	0	2	2	0	0	5	5
Mesoplodon stejnegeri	0	0	0	0	0	0	0	0	1	1	0	0	1	1
Physeter macrocephalus	0	0	0	0	3	0	3	1	0	0	0	0	6	1
Kogia breviceps	0	0	0	0	1	1	1	0	0	0	0	0	2	1
B. acutorostrata	0	0	0	0	0	0	0	0	1	0	0	0	1	0
M. novaeangliae	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Unidentified whale	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Unidentified delphinid	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Unidentified Cetacea	0	0	1	0	1	0	0	0	0	0	0	0	2	0
Total	14	8	64	53	82	62	69	59	53	46	66	60	348	291

(b) Set-net

	1990		1991		1992		1993		1994		Total	
Percent Coverage	4.4		10.4		12.7		15.0		7.5			
Species	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled	Kill	Sampled
Delphinus spp.	0	0	0	0	2	1	0	0	0	0	2	1
Phocoena phocoena	4	1	5	1	6	1	2	0	1	1	18	4
Total	4	1	5	1	8	2	2	0	1	1	20	5

Total body length was measured for 237 animals (130 males and 107 females), gonads were collected from 199 animals (110 males and 89 females), and teeth were collected and prepared for ageing from 94 animals (58 males and 36 females). The age and total body length data for each species sampled are summarised by state of sexual maturity for males and females in Table 2. Whole carcasses were collected by observers for 42 specimens (25 males and 17 females), and heads only were collected for 145 specimens (85 males and 60 females). All of the osteological materials (i.e. heads and post-cranial skeletons) have been archived at the Natural History Museum of Los Angeles County, Los Angeles, California (LACM) (Table 3).

Table 2

Summary of total body length and age by state of sexual maturity for each species sampled from the observed incidental kill of the California drift and set gillnet fisheries between 1990 and 1995. We present the sample size for each category. When gonads for a specimen were not available, sexual maturity could not be determined, and these samples constitute the 'Undeter.' (i.e. undetermined) category. Females are considered sexually mature when one corpus or more are present in either ovary. Sexual maturity in males can only be definitively determined by examination of histological preparations of testes tissue. We do not presently have these data available, and therefore used testes weight, which increases markedly when a cetacean attains sexual maturity, as a proxy for estimating state of sexual maturity. We used the following published information to estimate the state of sexual maturity for males in our sample: All testes weight criteria are for the weight of one testis, and a testis greater than the weight specified is considered mature. (1) For *Delphinus*, males with weight of one testis >200g are considered sexually mature (Ferrero and Walker, 1994), (2) for *Lissodelphis borealis*, >300g (Ferrero and Walker, 1993), (3) for *Lagenorhynchus obliquidens*, >50g (SWFSC unpublished data; Ferrero *et al.*, 1991), (4) for *Stenella coeruleoalba*, >50g (Miyazaki, 1984), (5) for *Tursiops truncatus*, >50g (Perrin and Reilly, 1984), (6) for *Grampus griseus*, >350g (Perrin and Reilly, 1984), (7) for *Phocoenoides dalli*, >33g (Kasuya, 1978) and (8) for *Ziphius cavirostris*, >150g (Mead, 1984). Total body length is recorded to the nearest 1cm, and age estimates are made to the nearest quarter of a year and assume a deposition rate of one growth layer group (GLG)/year. When $n>2$, the range of total body length or age is presented; otherwise the data for each specimen are presented in the column labelled 'RANGE', unless the data are not available (N/A). If no data are available for a category, the corresponding cell is left blank.

			Length (cm)			Age (years)		
Species	Sexual maturity		*n*	Median	Range	*n*	Median	Range
Delphinus delphis	Males	Immature	29	167	98-185	18	4.00	0.5-13.0
		Mature	39	188	174-210	23	12.50	8.0-26.0
		Undeter.	29	171	98-195	11	6.00	0.5-16.0
	Females	Immature	21	155	104-177	10	3.50	0.2-10.0
		Mature	19	177	166-197	10	10.00	5.0-16.0
		Undeter.	18	174	97-187	6	11.00	6.0-18.0
Delphinus capensis	Males	Immature						
		Mature						
		Undeter.	2		N/A; 120			
	Females	Immature	2		157; 159			
		Mature	3	195	177-210			
		Undeter.						
Delphinus spp.	Males	Immature						
		Mature						
		Undeter.	6	182	164-198			
	Females	Immature						
		Mature	1		163	1		12.0
		Undeter.	5	169	123-219			
Lissodelphis borealis	Males	Immature	4	203	182-215			
		Mature						
		Undeter.	4	193	186-255			
	Females	Immature	5	182	173-203	1		3.0
		Mature	7	214	200-217	5	14.00	11.0-16.0
		Undeter.	4	188	161-194			
Lagenorhynchus obliquidens	Males	Immature	1		181			
		Mature	5	188	178-198	2		7.0; 8.0
		Undeter.	2		180; 186	1		8.0
	Females	Immature	2		173; 178			
		Mature	2		193; 209	2		9.0; 14.0
		Undeter.	3	218	200-224			
Stenella coeruleoalba	Males	Immature	1		189			
		Mature						
		Undeter.						
Tursiops truncatus	Males	Immature	1		142			
		Mature						
		Undeter.						
Grampus griseus	Males	Immature	2		219; 243			
		Mature						
		Undeter.	2		252; 254			
	Females	Immature	2		225; 264			
		Mature						
		Undeter.	6	246	144-360			
Globicephala macrorhynchus	Males	Immature						
		Mature						
		Undeter.						
	Females	Immature	1		212			
		Mature						
		Undeter.	1		229			
Phocoenoides dalli	Males	Immature	3	181	174-182			
		Mature	4	208	203-211	2		6.0;10.0
		Undeter.	1		165	1		4.0

cont...

Table 2 (cont.)

Species	Sexual maturity		Length (cm) n	Length (cm) Median	Length (cm) Range	Age (years) n	Age (years) Median	Age (years) Range
Phocoenoides dalli	Females	Immature				1		8.0
		Mature	3	150	109-179			
		Undeter.	3	167	147-172			
Phocoena phocoena	Females	Immature						
		Mature						
		Undeter.	2		138; 152			
Kogia breviceps	Females	Immature	1		160			
		Mature						
		Undeter.						
Ziphius cavirostris	Males	Immature	1		435			
		Mature						
		Undeter.						
Mesoplodon carlhubbsi	Females	Immature	1		330			
		Mature						
		Undeter.						

Table 3

Sample sizes by species for the osteological material (i.e. heads and post-cranial skeletons) that have been collected by the National Marine Fisheries Service observers aboard drift and set gillnet fishing vessels between 1990 and 1995. The count of 'Head collected' includes only the specimens without post-cranial skeletons. The heads and post-cranial skeletons have been permanently deposited at the Natural History Museum of Los Angeles County, Los Angeles, California (LACM) where they are available for further study. All specimens with a carcass collected have teeth and soft tissue samples (i.e. gonads, stomach, adrenal glands, skin) archived and available for further study at the Southwest Fisheries Science Center, La Jolla, California. In general, specimens with a head collected also had available teeth and soft tissue samples collected by the observer in the field. Specimen and LACM accession numbers for all biological samples collected can be obtained by contacting the author (SJC) of this paper. Under the column labelled 'Sex,' 'M' denotes males and 'F' denotes females.

Species	Sex	Carcass collected	Head collected
Delphinus delphis	M	21	61
	F	9	33
Delphinus. capensis	M	0	1
	F	1	4
Delphinus spp.	M	1	0
	F	0	0
Lissodelphis borealis	M	0	9
	F	1	12
Lagenorhynchus obliquidens	M	1	6
	F	1	4
Stenella coeruleoalba	M	0	1
	F	0	0
Tursiops truncatus	M	1	0
	F	0	0
Grampus griseus	M	0	2
	F	2	1
Globicephala macrorhynchus	M	0	0
	F	0	1
Phocoenoides dalli	M	1	5
	F	2	4
Phocoena phocoena	M	0	0
	F	1	0
Mesoplodon carlhubbsi	M	0	0
	F	0	1

DISCUSSION

Biological sampling

Although working on small boats like those in the California drift and set gillnet fisheries can be difficult, the observers have demonstrated that collecting adequate biological data to describe the selectivity of these fisheries is possible. In fact, 59.1% of the observed incidental kill sampled included a complete suite of life history data (i.e. species identification, sex, total body length, gonads, teeth and skin were collected from a specimen), while 77.3% of the observed kill had at least a measurement of total body length recorded as well as the specimen's species and sex, and 93.5% had at least a skin sample collected. Additional sample material for a specimen may also have been collected and may include the stomach, a sample of blubber, muscle and some internal organs (see Jefferson *et al.*, 1994). When a whole carcass is collected by an observer, a complete suite of morphological measurements are made and all organs are weighed and samples preserved for future analysis. All tissue samples and the morphological data are archived at the SWFSC, and the osteological samples are archived at LACM.

Although the two *Delphinus* species represent 56.9% ($n = 198$) of the total observed incidental kill of the drift gillnet fishery, these two species represent 63.6% ($n = 185$) of all the biological specimen material collected and 76.2% ($n = 32$) of all the whole carcasses retrieved by observers (Table 1 and 3). This is due, in part, to the relative frequency with which these species are entangled and because these animals are small enough in size to be handled on the deck of a small fishing vessel.

Species identification

In our efforts to determine the accuracy of observer field identifications, we found more misidentifications than we expected. We noted a few errors in the identification of *Delphinus* species as well as other species whose identification cetologists tend to consider straightforward: *B. bairdii* and *G. macrorhynchus*. Although one or two errors may not seem significant, in the latter cases both species are considered 'strategic' stocks in the Pacific Ocean by the US (Barlow *et al.*, 1995a). Only a handful of animals belonging to these species are observed entangled each year, and each one markedly changes the mortality estimate (Julian and Beeson, 1997). Because observers are required to learn the identifications of a wide range of species (marine mammals, fish, birds and turtles) in order to describe the bycatch of gillnet fisheries, some caution must be exercised when evaluating identifications made in the field. The collection of skin samples is relatively easy for marine mammals as this NMFS observer program demonstrates, and the value of collecting these samples for confirmation of identification and population studies should be emphasised in all field programs.

Fishery selectivity

In part, because the drift gillnet fishery operates farther offshore and along a wider section of coastline, this fishery incidentally kills more cetacean species than the set gillnet fishery (Fig. 1). The NMFS observer program recorded 16

species of Cetacea among the incidental kill of the two California gillnet fisheries with several entanglements unidentified to species (Julian and Beeson, 1997; Table 1). This description of the incidental take of cetaceans is not markedly different from that reported by the California Department of Fish and Game (CDFG) observer program, which operated on these fisheries in the mid-1980s (Hanan *et al.*, 1993). The other CDFG reports (i.e. Diamond and Hanan, 1986; Hanan *et al.*, 1986; 1987; 1988; Herrick and Hanan, 1988; Hanan and Diamond, 1989) focused on the incidental kill of the set gillnet fishery, and all reported high entanglement rates for *P. phocoena*. Additionally, a report summarising the data on fishery interactions collected from stranded marine mammals along the coast of California from the San Luis Obispo county line south to the border of Mexico between 1975 and 1990, noted that the two *Delphinus* species were the most frequently occurring species (44.9%; $n = 31$) in the data set (Heyning *et al.*, 1994). Contrary to the NMFS observer data set described here, the *Delphinus* specimens identified to species included 19 (or 61.3%) *D. capensis* and 2 (or 6.4%) *D. delphis* (Heyning *et al.*, 1994). The reversal in representation of the two *Delphinus* species between the NMFS observer and stranding data sets reflects an inherent bias in data collected from stranded animals. Data from strandings are more likely to include species of *D. capensis*, a coastal species, rather than *D. delphis*, which is more pelagic in its distribution (Heyning and Perrin, 1994).

Although the number of samples are limited, the age and sex selectivity of the two gillnet fisheries does not appear to be particularly specific. Each fishery appears to take a wide range of length and age classes, including animals close to estimates of asymptotic total body length for most of the small cetacean species (see tables in Perrin and Reilly, 1984 for comparisons) (Table 2).

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